WISCONSIN DEPARTMENT OF NATURAL RESOURCES
RESEARCH REPORT 191
APRIL 2010

DNR ARCHIVE

Wisconsin Elk Habitat Suitability Analysis

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Abstract

An experimental elk herd of 25 animals was released into the Chequamegon National Forest near Clam Lake, Wisconsin in 1995. This herd thrived and increased to nearly 100 animals within 10 years. The project's experimental phase ended and responsibility for the herd transferred from the University of Wisconsin-Stevens Point to the Wisconsin Department of Natural Resources. In June 2000, the Wisconsin Natural Resources Board approved a management plan for the Clam Lake elk herd. This plan established core and buffer areas, described habitat and population management techniques, and set population objectives.

The success of the Clam Lake introduction and the attractiveness of elk has spurred several other localities around Wisconsin to voice an interest in establishing local elk herds. When adopting the Clam Lake management plan, the Natural Resources Board set forth guidelines for further reintroduction efforts. These guidelines require, among other things, the evaluation of the biological and ecological suitability of other areas for elk and indicate that factors such as the quality and quantity of available habitat, the amount and proximity of agriculture, and public attitudes regarding elk should be included.

Geographic information systems (GIS) have been valuable tools for the analysis of habitat suitability. Most past efforts, however, have considered the biological aspects of suitability, with little effort focused on social information or on identifying potential conflicts with other resources or land uses. In addition, past efforts to model habitat have covered either a very large area (e.g., a state or larger) or a more specific area (e.g., a county or other smaller area).

We developed a GIS-based habitat suitability model using ArcInfo® (ESRI, Redlands, CA) for the state of Wisconsin. Data inputs to the model included both biological elements (mostly land cover information derived from satellite imagery) and social elements (agriculture, road density, and land ownership). The intent of this model was to conduct a statewide evaluation of areas potentially suitable for elk reintroduction.

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We identified 15 areas of "suitable" elk habitat in Wisconsin. Most areas were located in the northern forest region of the state, with two patches in the central forest. Suitable elk patches generally had sufficient forest cover (both deciduous and coniferous) with little to no agriculture, low road density, and large amounts of public land. Suitable patches ranged in size from 192 km^2 (79 mi^2) to over 6,000 km^2 (2,450 mi^2). Winter cover was the least suitable of the biological elements. We also identified potential conflicts with captive elk herds and rare plant species for each suitable patch.

Some caution must be exercised when interpreting our statewide results. We used only generalized land cover information, which could result in areas identified as being suitable actually having very low habitat quality. Thus, it will be important to evaluate these areas in more detail with more specific forestry and social information.

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Introduction

Eastern elk (*Cervus elaphus canadensis*) were native to Wisconsin, but were extirpated in the mid- to late 1800s (Schorger 1954). Native North Americans in northern Wisconsin regularly hunted elk in the Bayfield, Ashland, and Sawyer county area. Schorger (1954) reported that the last elk probably disappeared from Wisconsin in 1868. Parker (1990) described the historic range and provided additional history of elk in Wisconsin.

In 1989, the Wisconsin Legislature initiated a program through the Wisconsin Department of Natural Resources (Wisconsin DNR) to determine the feasibility of reintroducing elk in Wisconsin. The Wisconsin DNR concluded that the Moquah Barrens in Bayfield County had potential as a restoration site and prepared a management plan for a herd reintroduction (Parker 1990). Local opposition to potential crop losses associated with elk reintroduction, however, led to a decision not to initiate reintroduction.

Several proponents of elk reintroduction explored other potential Wisconsin release sites and approaches to reintroduction following this initial decision. These proponents concluded that the Glidden and Hayward Ranger Districts (now the Great Divide District) of the Chequamegon National Forest appeared to have the necessary requirements for a successful elk reintroduction effort without the potential for crop depredations. Faculty at the University of Wisconsin-Stevens Point (UWSP) proposed a four-year feasibility study (1995-99) to release a small herd of elk and monitor their behavior and condition, their impacts on other natural resources, and the reaction of people to elk in the area. If the study demonstrated reintroduction of elk was feasible, the goal was to reintroduce a managed herd of wild elk into Wisconsin on the Chequamegon National Forest. If the reintroduction was determined to be unfeasible, however, the experimental herd would be removed from the wild.

On May 3, 1995, 25 elk (7 bulls and 18 cows) from Michigan were released into the Chequamegon National Forest near Clam Lake following a welcoming song and a pipe ceremony by Eugene Begay, a Lac Courte Oreilles Chippewa spiritual leader. All animals had been quarantined, tested for disease, and radio-marked prior to release. The herd reproduced successfully and grew to almost 50 animals by the fall of 1998, then 146 in September 2008. The main herd has remained near the release site occupying 100 km^2 of the 1,000 km^2 study area. Few concerns of damage to agricultural or forest crops have been raised and local people have generally supported the reintroduction. At the conclusion of the UWSP feasibility study in the summer of 1999, a project to establish free-ranging elk in Wisconsin was seen as favorable. A management plan for continuing the restoration of the Clam Lake elk herd was developed (Wisconsin DNR 2000), with recognition that impacts from the growing elk herd would likely intensify as the population continues to grow to the management goal of 500 animals. A need existed, therefore, for the monitoring and assessment of the biological and socio-economic impacts of the herd.

The goal of the current project was to analyze and present biological and social information to both state and tribal decision makers regarding the suitability of different regions of Wisconsin for elk reintroduction efforts. Specifically, we:

1. Predicted statewide habitat suitability using UWSP's elk data, other Midwest data (e.g., Beyer 1987), and WISCLAND satellite imagery.
2. Used geographic information system (GIS) to identify areas of suitable habitat (Didier and Porter 1999).
3. Created a store-house of information on Wisconsin elk.

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Methods

A statewide spatial model of potential elk reintroduction sites was constructed using ESRI ArcInfo® and ERDAS® software. We modified the methods described by Didier and Porter (1999), allowing us to conduct the analysis on the entire state. Whereas Didier and Porter (1999) eliminated large areas of the state of New York in "stage 1" prior to the spatial suitability analysis, such a determination was not made in this project prior to implementing our model. Thus, the relative suitability for the whole state was assessed.

The primary data source for the land cover information used in the model was the WISCLAND data set. This multi-date classified LANDSAT Thematic Mapper imagery was acquired from fall 1991, spring and fall 1992, and spring 1993, with a resolution of 30 m. We used Level 2 classification (see Appendix for a discussion) of land cover which has three classes of urban, two classes of agriculture, and nine classes of upland or wetland land cover (i.e. Grassland, Deciduous Forest, Coniferous Forest, Mixed Forest, Emergent Wetland, Lowland Shrub, Forested Wetland, Barren, and Shrub). Since errors may occur in the classification of satellite imagery, we conducted a sensitivity analysis of the potential errors on model results (see Appendix).

Road information was derived from the U.S. Geological Survey's (USGS) digital line graph data. Road density grids were calculated and four-lane highways were buffered. We compiled land ownership grids from multiple data sources.

Three biological components important to elk have been identified in the Midwest: winter foods, winter cover, and spring foods (Beyer 1987). Two social elements also found as important were used in this Habitat Suitability Index (HSI): road density (Didier and Porter 1999) and land ownership. Thus, the WISCLAND grid data set was used to derive the three biological components, while the road density grid data and land ownership grid data were used to derive the social components.

The general model approach was to assign a suitability value, ranging from 0 to 1, to each grid cell, for each biological component. The result was called the suitability reclassification. To obtain a landscape assessment of each component, a 100 km^2 moving window was used to calculate the average suitability value for each element (hereafter called "focal mean"). The resulting focal mean grids were then used to calculate a final suitability value grid. Agricultural areas and four-lane highways were blocked or masked out of the final model.

Biological Elements

Beyer (1987) identified three biological components that may be limiting factors for elk in the Midwest: winter cover, winter foods and spring foods. He constructed an HSI model used to evaluate individual forest stands for elk suitability (Table 1a). Beyer's HSI categories included timber-stand types as those stands were delineated in timber cruise data obtained by land managers. These HSI values were modified to apply to the WISCLAND classification system (Table 1b). We used Level 2 classification (generalized cover classes) rather than Level 3 (specific cover classes) because Level 2 accuracy was consistent statewide whereas Level 3 was not.

We applied a minimum area criterion to the reclassified WISCLAND data set. Once suitability values were assigned, a minimum area (2 ha) was applied to the data. This criterion was based on the minimum area map unit of the WISCLAND data set. WISCLAND data are displayed at a 30-m by 30-m pixel size. It is unlikely that elk recognize

Table 1. Habitat Suitability Index (HSI) values as determined by Beyer (1987) for forest stands in Michigan (a) and modified HSI values for Level 2 classes in WISCLAND data set as used in the Wisconsin HSI model (b).

	Forest Stands from Beyer (1987)	Winter Cover	Winter Foods	Spring Foods
1a.				
	Aspen	0.3	1.0	0.7
	Maple		1.0	0.5
	Oak		0.7	0.4
	Other Hardwoods		0.5	0.3
	Cedar	1.0	1.0	0.7
	Swamp Conifer		0.2	0.5
	Upland Conifer	0.5	0.7	0.5
	Wildlife Openings	—	—	1.0
	Natural Openings	—	—	0.7

	Level 2 Classes in WISCLAND	Winter Cover	Winter Foods	Spring Foods
1b.				
	Grassland	0	0.3	0.7
	Deciduous Forest	0.3	0.9	0.7
	Coniferous Forest	0.5	0.7	0.5
	Mixed Forest	0.3	0.5	0.3
	Emergent Wetland	0	0	0.7
	Lowland Shrub	0.3	0	0.2
	Forested Wetland	1.0	0.6	0.6
	Barren	0	0	0
	Shrub	0.3	0.2	0.5

and select areas based on small blocks, but rather on a landscape scale. For this reason, suitability values were averaged using a focal mean function. This "neighborhood" function applied a moving window across the data. Thus, the individual suitability values in each grid cell were changed according to the average suitability of all the cells within 100 km^2 (45 mi^2) of the processed cell. The area of the moving window was based on the area occupied by the Clam Lake elk herd in 2000. The resulting cell value in each focal mean grid represented the average suitability of the biological resource within 100 km^2 of that cell, and was called a resource suitability value (WF_{SV} [Winter foods], WC_{SV} [Winter cover], SpF_{SV} [Spring foods]).

Social Elements

Four social elements were included in the final display of "suitable habitat." Two were included in the geometric mean calculation and two were applied as masks. Road density and land ownership were treated as habitat variables (i.e., they were reclassified and average suitability values were calculated). Agriculture and 4-km road buffers were used as a mask to eliminate unsuitable areas from the final model results.

Roads were delineated from the USGS digital line graph data set. Only state and county roads were used to calculate road density. Interstate four-lane highways were incorporated into masks. A 1-km by 1-km grid was used to calculate the number of kilometers of road within each cell of the grid. The resulting grid was the density of state and county roads in km of roads per square km of land. Suitability values were assigned to areas based on road density (Figure 1, based on Didier and Porter 1999). The focal mean was calculated from this road density grid. The cell values in the focal mean grid depict road suitability within 100 km^2 (RD_{SV}) of each cell.

The land ownership coverage was reclassified based on suitability values found in Table 2. Values were based on the ability, or desire, of land management entities to manage their land base for elk or elk habitat. After suitability values were assigned to land ownership categories, we applied a minimum area criterion, similar to the habitat variables, and calculated an average suitability using a focal mean statistic. The resulting grid depicted land ownership suitability within a 100 km^2 area (LO_{SV}).

Masks

Two masks were created to block out areas where elk were not desired or known to have no suitability for elk: agricultural/urban land and areas within 4 km of a four-lane highway. We used WISCLAND to identify all areas of agriculture (all agricultural classes). These areas (AU_{SV}) were assigned a suitability value of 0. We identified all four-lane roads from the USGS digital line graph and buffered them with a 4-km buffer. These areas (RD_{Buffer}) were assigned a suitability value of 0.

Final Suitability and Suitable Patches

The final suitability value (FSV) for elk habitat in Wisconsin was determined using the following formula:

$$FSV = [(WF_{SV} * WC_{SV} * SpF_{SV} * RD_{SV} * LO_{SV})^{1/5}] * AU_{SV} * RD_{Buffer}$$

A geometric mean was used to calculate the final suitability value. This caused the FSV to be 0 if any suitability value was 0.

The final suitability grid was a continuous grid with each cell containing a suitability value between 0 and 1. Except for those areas assigned a suitability value of 0 using a mask, all areas of the state had some level of suitability. The next task was to identify areas or patches in the final suitability grid that were considered "suitable."

The area occupied by the existing elk herd near Clam Lake was used as a reference. Based on that area, the requirements for a "suitable" patch were defined as an area having a mean FSV being ≥ 2 standard deviations below the FSV of the Clam Lake area and ≥ 100 km^2 in size. In addition, if any patch had a minimum width < 4 km, that patch was split at that point yielding 2 patches, which each had to meet the above criteria.

Table 2. Suitability values assigned to land ownership categories.

Land Ownership Category	Suitability Value
County Forests	0.8
National Forests	0.8
National Wildlife Refuges/ National Parks	0.8
Private	0
Private (MFL – Industrial)	0.5
Private (MFL – Non-industrial)	0.5
Private (FCL)	0.5
Tribal Reservations	1
State Fish and Wildlife Areas	1
State Forests	1
State Natural Areas	1
State Parks and Trails	1
State Riverways	1

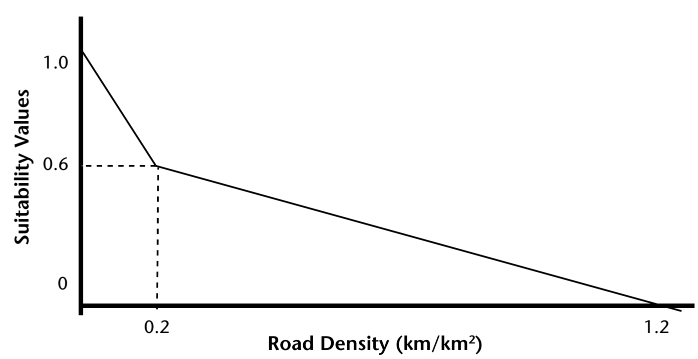


Figure 1. *The relationship between road density and suitability values used in the Wisconsin elk HSI model.*

Conflict Identification

In addition to delineating areas of the state that may be suitable for elk reintroductions, GIS can also aid in identifying areas of conflict due to elk reintroductions. For example, an elk population may have impact on other resources such as damage to threatened and endangered vegetative species. Elk have the potential to graze or browse threatened and endangered plant species. Land managers and local governments may have concerns if there are many rare plant species present in an area of potential reintroduction. Overlaying records of rare plants on the grid of suitable elk patches in the GIS format allowed us to identify such potential conflicts.

Similarly, there are also concerns about disease issues. Elk have been shown to carry chronic wasting disease (CWD) and bovine tuberculosis (bovine TB). Both of these diseases are of concern in Wisconsin. There is no evidence of bovine TB present in wild deer or elk in this state, but because of the bovine TB outbreak in Michigan and the presence on some Wisconsin captive cervid farms, state officials are on guard. CWD has been identified in southern Wisconsin and constitutes a risk to wild elk populations in this state. To reduce the risk of further introduction of CWD or diseases into Wisconsin, any other elk released into the state should come from disease-free herds. However, several captive elk herds are already present in Wisconsin and the disease status of these herds is unknown. To prevent disease from spreading from a captive situation to wild populations, releasing elk far from captive ranches may be desirable. Thus we overlaid elk ranches, derived from information obtained from the Department of Agriculture, Trade and Consumer Protection, on top of identified potential suitable elk patches, to further refine suitable areas.

Results

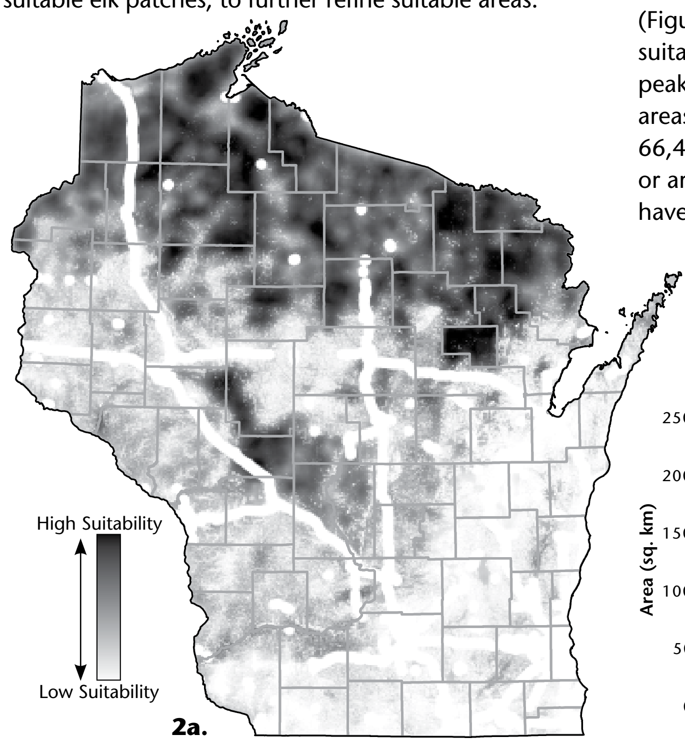
Biological Elements

Table 3 shows the mean, standard deviation, and range of suitability values of the three biological elements after focal calculations and the final run of the model. Winter cover had the lowest statewide average suitability (Table 3). Winter foods and spring foods had similar suitability values, and were higher than winter cover. Winter cover reclassification values for WISCLAND cover types (Table 1b) were generally lower than reclassification values for spring and winter foods indicating that the forest cover types present in Wisconsin provide poor thermal cover. Winter and spring foods had higher reclassification values for WISCLAND cover types and thus produced statewide maps of generally higher suitability values.

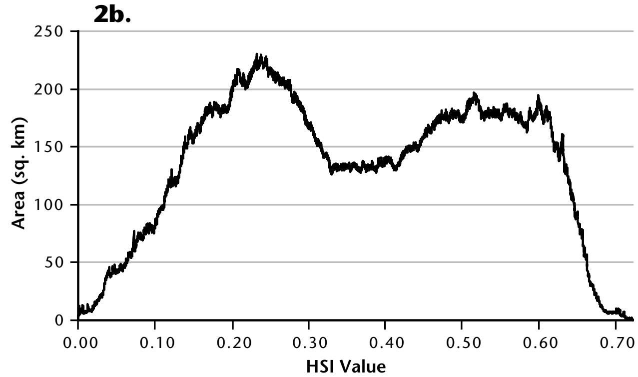
Table 3. Mean, standard deviation, and range of HSI values of the three biological elements after focal calculations and the final run of our HSI model.

Model Component	Mean Suitability (Maximum = 1.0)	Standard Deviation	Range
Winter Cover	0.18	0.13	0 – 0.62
Winter Foods	0.38	0.21	0 – 0.85
Spring Foods	0.38	0.16	0 – 0.68
Final Suitability	0.22	0.22	0 – 0.72

Final Suitability. Areas of relatively high suitability are concentrated in northern Wisconsin with a smaller block in the central forest (Figure 2a). The distribution of final suitability values > 0 shows two peaks of relatively large areas of suitability. The first peak occurs at about HSI = 0.22 (Figure 2b) and corresponds to large areas of marginal suitability in southern Wisconsin (Figure 2a). The second peak occurs around HSI = 0.55 and represents suitable areas in the north. These averages do not include the 66,457 km^2 which are either in agriculture/urban land use or are within 4 km of a four-lane highway. These areas all have a 0 suitability value.



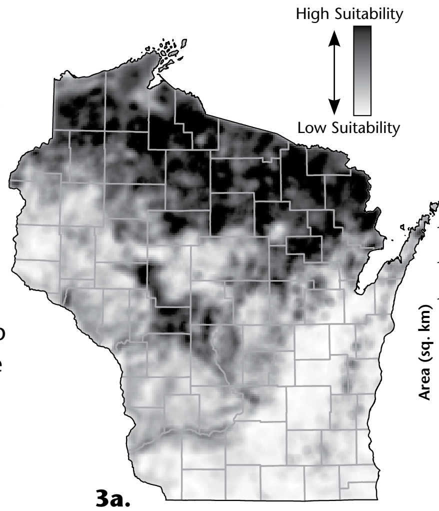
2a.



2b.

Figure 2. *Final suitability map (a) and the total area occupied by each value (b) in the final suitability model.*

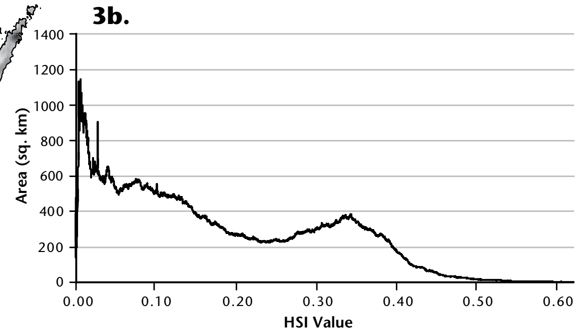
Winter Cover Suitability. Most of the high-quality winter cover occurs in a few small patches in northern Wisconsin (Figure 3a). The largest areas of the state had relatively low suitability values for winter cover (Figure 3b). Most of the large blocks of land had suitability values ≤ 0.1. There was a small peak of relatively high suitability values (between 0.3 and 0.4) and this peak corresponded to larger areas of swamp conifer in the north. Overall there was very little variation in HSI values for winter cover (Table 3) because of the consistently low values observed statewide.



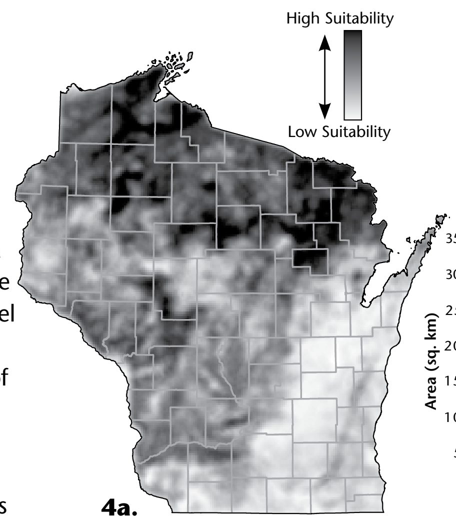
3a.

Figure 3. *Winter cover suitability map (a) and the total area occupied by each value after the focal calculations (b).*

3b.



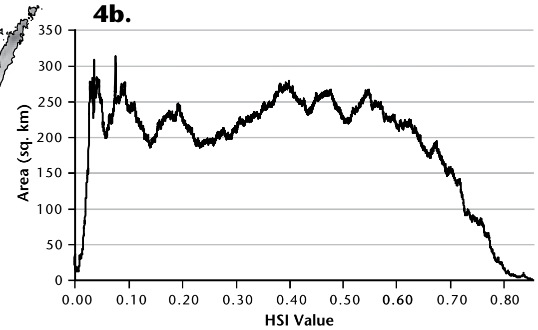
Winter Foods. Unlike winter cover, winter foods had relatively large areas of suitability spread throughout the north and central forests (Figure 4a). The suitability values for these areas ranged from < 0.1 to > 0.6 (Figure 4b). It was not until suitability values rose above 0.7 that the area declined to nearly 0. As a result of this relatively equal representation of a wide range of suitability values, the variation associated with this model element was the largest (Table 3). Most of the highly suitable areas of winter foods were in the northern and to a more limited extent the western portion of Wisconsin and are represented by both deciduous and coniferous forests.



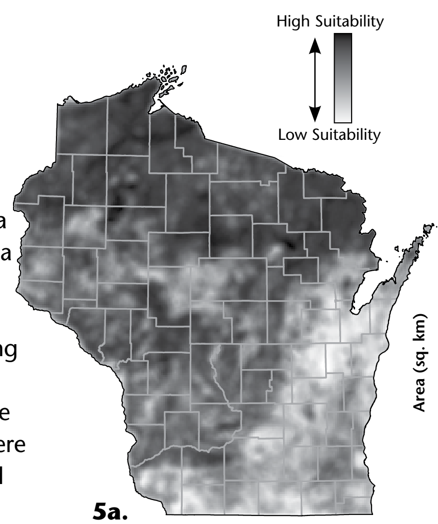
4a.

Figure 4. *Winter foods suitability map (a) and the total area covered by each value after the focal calculations (b).*

4b.



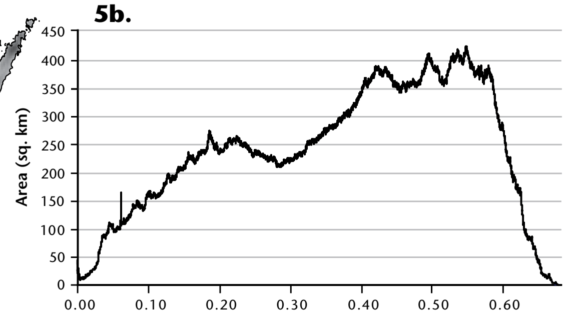
Spring Foods. Spring foods were better distributed throughout Wisconsin, with a few areas of high suitability in the north (Figure 5a). Spring foods exhibited a slow rise in area of each suitability value until the maximum area was reached at a HSI value of 0.5 to 0.6 and then area declined rapidly to 0 near HSI value of 0.7 (Figure 5b). The statewide variation of suitability values in spring foods was intermediate between winter cover and winter foods (Table 3). The high quality spring foods were identified in the north and west and are represented by grasslands and some wetland types.



5a.

Figure 5. *Spring foods suitability map (a) and the total area covered by each value after the focal calculations (b).*

5b.



Masks

There was a total of 47,580 km^2 of agricultural/urban areas in the WISCLAND data which were masked out in the final suitability model. Likewise, there were 18,880 km^2 that were included in the 4-km buffer on either side of all four-lane highways. These two masks assigned a suitability value of 0 to 66,460 km^2 of land.

Suitable Patches

The mean HSI value for the area occupied by elk in the Clam Lake area was 0.59 (sd = 0.029). The mean minus two standard deviations (HSI = 0.53) was used to identify "suitable patches." We identified nearly 400 suitable patches using this process. We then applied the minimum area criterion and the minimum width criterion to identify 15 patches which met our definition of suitable for elk (Figure 6). The area and various suitability values for each model element in each patch are provided in Table 4 and in Figure 7.

Two large patches (Table 4, patch 4 and 11) were identified in the north central and northeast portions of the state (Figure 7b). Only one other patch was > 1,000 km^2, with most of the others between 200 and 600 km^2. All patches had mean HSI values > 0.55 (by definition), but no patch had a mean HSI value > 0.6 (Figure 7a). Winter cover represented the biological element which had the lowest mean suitability values, consistent with statewide trends. The highest winter cover suitability value was 0.41 and was found in patch 12 (Figure 7d). Winter foods represented the biological element with the highest suitability values ranging from 0.56 to 0.8 (Figure 7e), again consistent with statewide trends in winter foods. Spring food suitability values were intermediate to winter foods and winter cover ranging from 0.46 to 0.64 (Figure 7c). Public land HSI values ranged from 0.44 to 0.70, while the road density HSI values were consistently high ranging from 0.82 to 0.95 (Figures 7f and g).

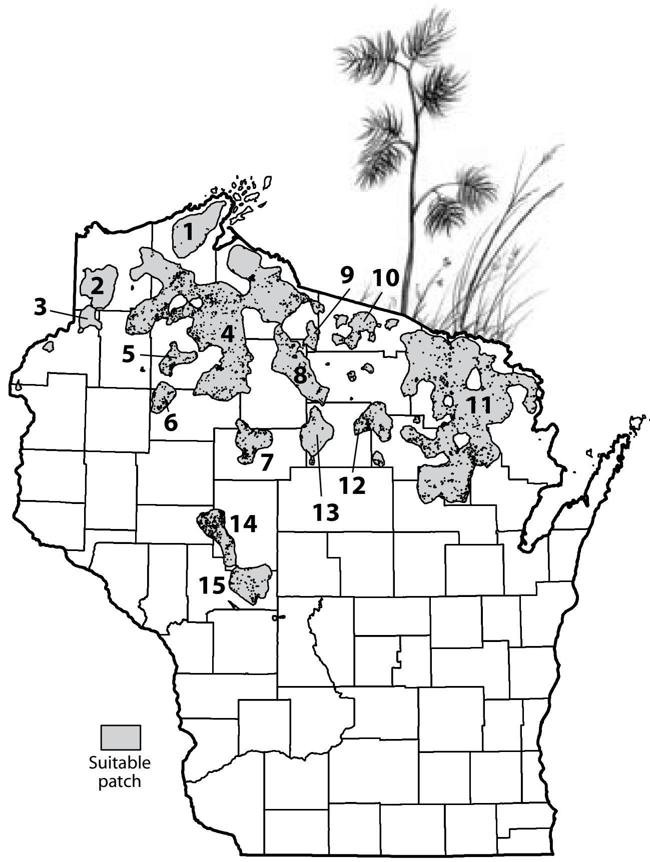


Figure 6. *Locations of the largest patches identified as suitable using the Clam Lake criteria.*

Table 4. Average area (km^2) and suitability values for biological elements, public land, and road density for patches found to be suitable for elk.

			Biological Elements			Social Elements	
Patch	**Area (km2)**	**Mean HSI**	**Winter Foods**	**Winter Cover**	**Spring Foods**	**Public Land**	**Road Density**
1	853	0.60	0.72	0.30	0.60	0.64	0.95
2	627	0.57	0.56	0.37	0.51	0.64	0.89
3	191	0.56	0.57	0.34	0.53	0.56	0.92
4	6,239	0.60	0.66	0.39	0.57	0.61	0.91
5	309	0.57	0.72	0.31	0.60	0.60	0.82
6	274	0.60	0.80	0.29	0.64	0.56	0.91
7	515	0.58	0.66	0.36	0.56	0.58	0.89
8	1,022	0.58	0.56	0.39	0.53	0.62	0.95
9	154	0.55	0.48	0.37	0.46	0.70	0.91
10	338	0.57	0.60	0.33	0.50	0.68	0.87
11	6,452	0.60	0.69	0.38	0.57	0.62	0.89
12	511	0.58	0.68	0.41	0.59	0.50	0.84
13	544	0.59	0.72	0.39	0.62	0.44	0.92
14	565	0.59	0.66	0.35	0.59	0.63	0.85
15	651	0.58	0.60	0.34	0.55	0.67	0.92

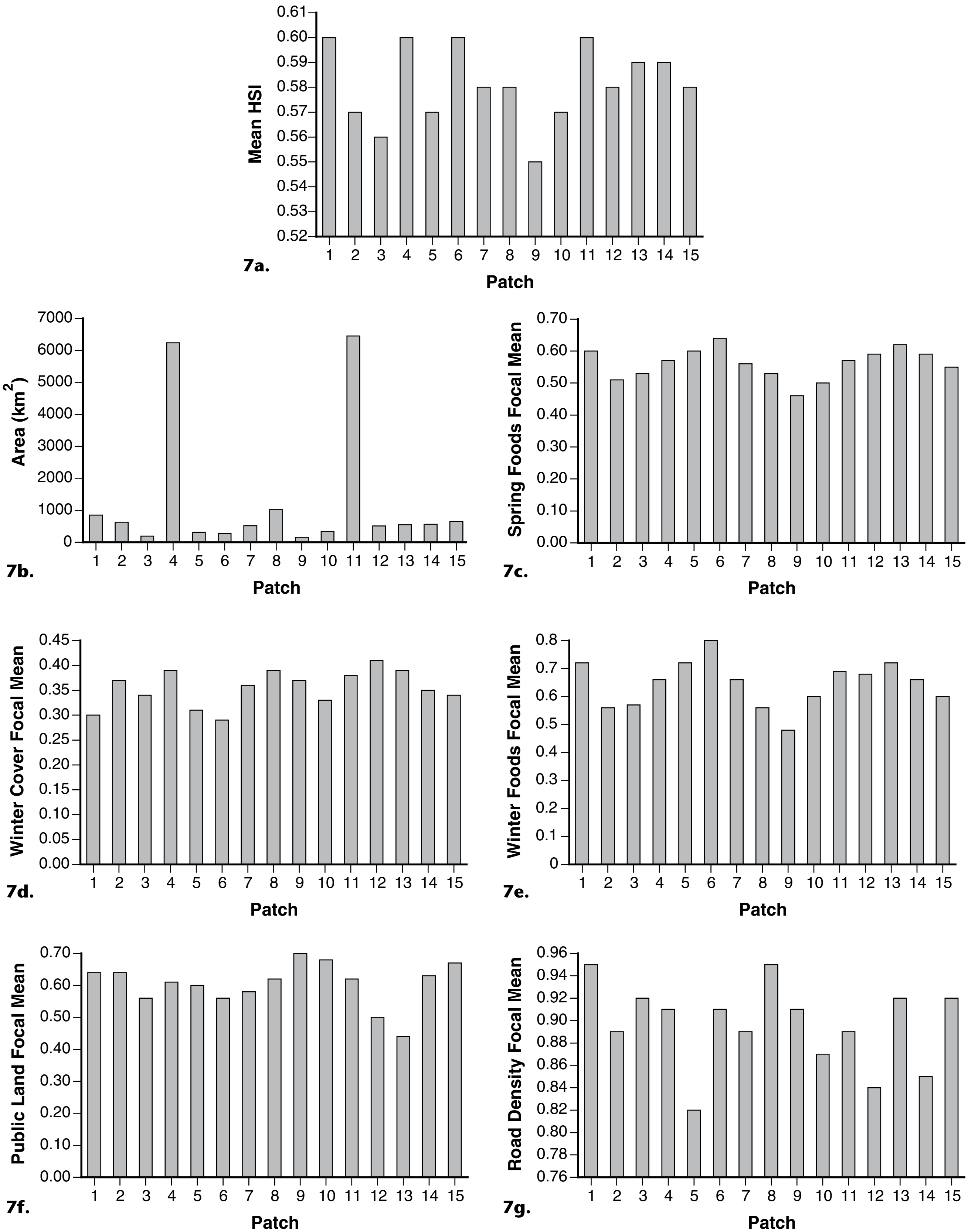
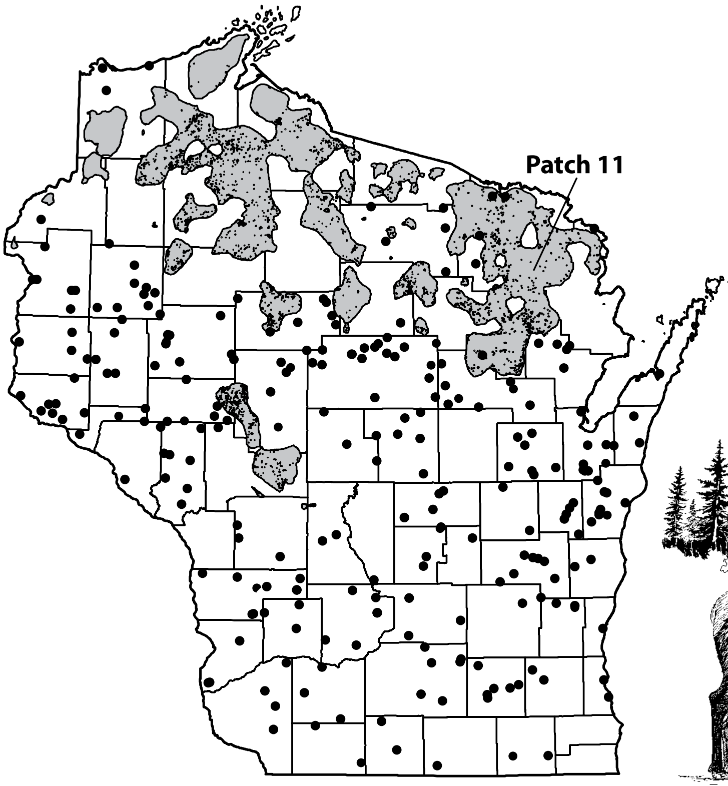


Figure 7. *Statistics of patches identified as suitable by the HSI model. The mean HSI value for each patch is provided in (a). The area of each patch is provided in (b). Graphs (c), (d), and (e) show the average suitability value for each biological element in each patch, while graphs (f) and (g) show suitability values for the two social elements.*



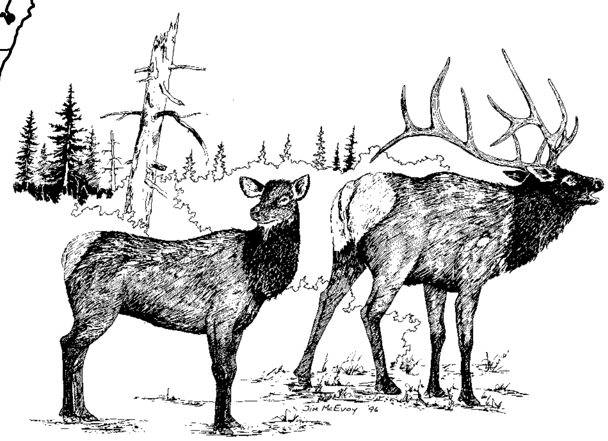


Figure 8. *Wisconsin Department of Agriculture, Trade and Consumer Protection data showing locations of registered game farms with elk or red deer noted as present.*

Conflict Identification

We identified 258 game farms in Wisconsin that had elk or red deer (same species) as either a primary or secondary species present at the game farm. These game farms were scattered throughout Wisconsin but relatively few were found in the north (Figure 8). Of the game farms with elk present, five were found within the patches identified as suitable by our model. Those five game farms were in patch 11 in the northeast part of the state (Forest County).

Discussion

GIS has proved to be a useful tool in conducting a spatial analysis of suitable elk range in Wisconsin. Data from a variety of sources can be brought together in a GIS and the data used in complex ways to evaluate the potential of successful elk reintroduction. In addition to evaluation of potential habitat, GIS analyses were useful in identifying potential conflicts with other resources.

Our current analysis shows that the northern forest regions of Wisconsin all have some potential for successful elk reintroductions. Some areas of the north rank higher than others, but the entire north has some degree of potential. The central forest region of Jackson and Clark counties also shows potential for elk reintroductions, but this area is surrounded by land identified as either less suitable or unsuitable.

Another use of this HSI map is to identify areas of "unsuitability," areas where we know that elk will either not have enough resources to meet their needs or likely will become nuisance animals. Those areas which are at low suitability and especially areas with 0 suitability should be avoided as potential elk reintroduction sites. The caution to potential restoration of elk in the central forest in particular is that it is surrounded by unsuitable land uses. Education of central forest landowners to the potential of elk damage and effective controls must be put into place to keep elk from becoming a problem should they be reintroduced in these areas.

The other potential conflicts, which were identified using this GIS process, were disease transmission and impacts to threatened and endangered species. The occurrence of game farms with elk or red deer within a suitable patch was identified. Potential disease threats could exist with these game farms. To have a wild elk herd in proximity to a potential disease source would be unwise, thus potential elk restoration sites should avoid areas with concentrations of elk game farms. Several areas identified as suitable do not contain captive elk farms within them. Terrestrial threatened and endangered plant sites within patches were also identified. While the presence of elk may not affect these species, a review of the types of plants in a patch should be conducted before an elk release is made.

Appendix: WISCLAND Overview and Sensitivity Analysis Results

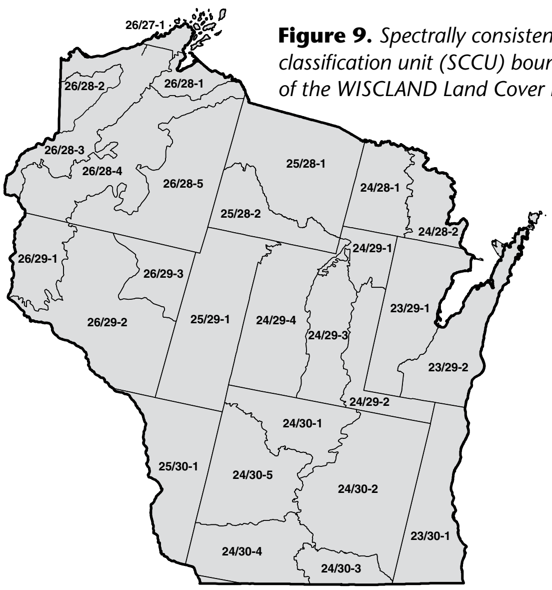


Figure 9. *Spectrally consistent classification unit (SCCU) boundaries of the WISCLAND Land Cover Project.*

WISCLAND Overview

In 1993, a consortium of government and private organizations was formed to sponsor the development of a statewide land cover data layer for Wisconsin. LANDSAT Thematic Mapper satellite imagery scenes were acquired dating from fall 1991, spring and fall 1992, and spring 1993. With one exception, each area of the state has both spring and fall images. The images have a resolution of 30-m pixels.

Over 20,000 ground truth sites were inspected and used to help automate the process of recognition and differentiation of different land cover classes. A guided clustering technique was used to perform the analysis. Each satellite scene was sub-divided into spectrally consistent classification units (SCCU) based on ecological similarity. Each SCCU was then analyzed for cover type. A map of the SCCUs is shown in Figure 9.

A three level hierarchy of cover type was assessed for the state, of varying levels of detail. Level 1 is the most general, categorizing the state's land cover in eight categories. Level 2 further breaks down each Level 1 category, yielding 16 categories. For example, Forest at Level 1 will be classified into Coniferous, Deciduous, and Mixed Forest at Level 2. For some areas of the state, it was also possible to further break down the Level 2 categories, into Level 3. For example, Deciduous Forest at Level 2 would be further classified into Aspen, Oak, Northern Pine, etc. at Level 3. For a variety of reasons, not all areas in the state were able to be classified down to Level 3 detail. Our statewide analysis used Level 2 data because it is more detailed than Level 1, the Level 2 classification existed statewide (unlike Level 3), and was of higher overall accuracy than Level 3.

Error Matrices

Through the use of ground truth data, the accuracy of the classification for each level was assessed and shown in error matrices. The matrix compares, for each class, its verified cover type from ground truthing of selected sites ("Reference" column) with its computer classified cover type for those same sites ("Classified" rows). Errors can be of two types: errors of omission and errors of commission. Errors of omission occur when a cell is incorrectly omitted from classification into a particular cover type. Errors of commission occur when a cell is incorrectly committed to classification of a particular cover type. This accuracy assessment occurs for each cover type, in each SCCU.

Figure 10 shows the accuracy matrix for SCCU 26/28-5 (uplands). There is one row and one column for each class. Diagonal entries represent the number of polygons correctly classified. Non-diagonal entries are the number of polygons incorrectly classified, where columns represent errors of omission and row entries are errors of commission. For example, for cover type 175 (Broad-leaved

	Reference									
Classified	**110**	**150**	**161**	**175**	**190**	**200**	**240**	**250**	**Total**	**User's**
Agriculture (110)	60	2		1			4	2	69	87%
Grassland (150)	5	12		6			1		24	50%
Coniferous Forest (161)			35		1				36	97%
Broad-leaved Deciduous (175)	1	1		181	4			1	188	96%
Mixed Deciduous/Coniferous (190)			7	4	6				17	35%
Open Water (200)						17			17	100%
Barren (240)	2	1			9				12	0%
Shrubland (250)		2						3	5	60%
Total	68	18	42	192	20	17	5	6	368	
Producer's	88%	67%	83%	94%	30%	100%	0%	50%		
No. Correct	314									
Overall	85%									
KHAT	78%									

Figure 10. *Accuracy matrix for SCCU 26/28-5 (uplands).*

Deciduous), 181 polygons were assigned correctly, relative to a total of 192 (column total) known to be Deciduous from ground truth. Thus, 11 were erroneously omitted from their correct class, one going to Agriculture (110), 6 going to Grassland (150) and 4 going to Mixed Coniferous/Deciduous (190). This yields 94% correct and is entered as the "Producer's" entry. In the row entry for Deciduous, 181 polygons were classified correctly, but 7 erroneously committed to this class when they belong to other classes. This yielded 96% correct as the "User's" measure of accuracy, referring to users of the data needing to know the probability that the classified polygons will actually be of that cover type on the ground.

Sensitivity Analysis

The goal of the sensitivity analysis was to find out how sensitive our model is to the classification errors described in the error matrices. To do this, one cover type in one SCCU was selected and its commission and omission errors corrected for. Cover type 190 was chosen because it had the lowest accuracy rating of any Level 2 cover type in SCCU 26/28-5. This SCCU was chosen because it is in this SCCU that the Clam Lake main elk range currently exists. The sensitivity analysis was done by noting the percentage of polygons incorrectly committed and omitted from 190 and randomly selecting that percentage of cells and removing them from the incorrect cover type class and committing them to the correct cover type class. The cells were randomly selected because although the matrix gives information regarding how much error exists there is no information on where within the SCCU the error is.

For example, 7 of the 17 polygons that should be 190 were erroneously committed to 161 (Coniferous). Thus 41% of the current 190 cells in this SCCU were randomly selected and reassigned to be of cover type 161. Likewise, this reassignment was also done with cover type 175. For errors of omission, the reassignment was reversed. Nine out of 20 polygons were erroneously omitted from 190 and placed in 240 (Barren). Thus 75% of current 240 cells in the SCCU were randomly selected and reassigned to 190. This was repeated for 161 and 175.

These reassignments were made which resulted in a "revised" land cover layer (for this SCCU only). This revised layer was then run through the same model process to see how different the revised final grid would be from the original final grid. In particular, the Clam Lake areas were compared before and after the sensitivity analysis. Table 5 shows the comparison of final suitability values for this area between the two versions.

Table 5. Final suitability values for the original and revised final grids for the Clam Lake area.

	Minimum	Maximum	Range	Mean	Standard Deviation
Original Final Grid	0.0000	0.6279	0.6279	0.5866	0.0288
Revised Final Grid	0.0000	0.6527	0.6527	0.5870	0.0372

As shown above, the revised FSV mean of the Clam Lake area is essentially the same as the original FSV mean of the area. One reason for this is although Mixed Forest had the lowest accuracy rating of Level 2 data in this SCCU, the Mixed Forest cover type accounted for relatively little area in the SCCU. Table 6 and Figure 11 show the percent cover type of Mixed Forest and the three other cover types it was confused with according to the error matrix, before and after the reassignments.

Table 6. Original and revised cover type percentages for spectrally consistent classification unit (SCCU) 26/28-5. See Figure 9 for the location of this SCCU.

Grid	Value (true) 1 Cell Count	Value (false) 0 Cell Count	SCCU Total Cells	Cover Type % of Total
Original % Cover Types				
Mixed 190	680295	9513537	10193832	6.7%
Barren 240	141495	10052337	10193832	1.4%
Coniferous 161	232768	9961064	10193832	2.3%
Deciduous 175	4211980	5981852	10193832	41.3%
Revised % Cover Types				
Mixed 190	446823	9747009	10193832	4.4%
Barren 240	36947	10156885	10193832	0.4%
Coniferous 161	499247	9694585	10193832	4.9%
Deciduous 175	4283521	5910311	10193832	42.0%

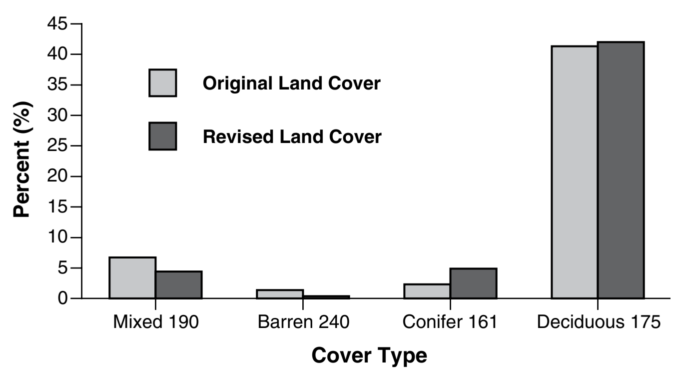


Figure 11. *Original and revised cover type percentages for SCCU 26/28-5.*

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Acknowledgments

This study was supported with funding from the Wisconsin DNR, Great Lakes Indian Fish and Wildlife Commission (GLIFWC), and Rocky Mountain Elk Foundation. Many people and groups were involved in collecting data for this work including the University of Wisconsin-Stevens Point and Chequamegon-Nicolet National Forest. This manuscript was improved by comments from the Wisconsin DNR Deer/Elk Advisory Committee and GLIFWC Biological Services Director, Neil Kmiecik. Help was provided by Wisconsin DNR Geo Services Section in map production and layout; especially we would like to recognize Bill Ceelen and Bill Shockley. Finally, thank you to all who wish to see elk thrive in Wisconsin.

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PUB-SS-591 2010